PERM Tin whiskers users group: 8-81H Risk modeling

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PERM 23

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Modeling

- Qualitative versus quantitative risk modeling
  - Qualitative is useful.
    - Clearly some conditions have more risk than others
  - Quantitative is more useful
    - ADHP uses quantitative probability and prediction process
    - Can be good for quantitative relative risk calculations
    - Be careful with absolutes
- Current model seeks to be quantitative where possible; Can do the following
  - Compare different whisker length and density statistics
  - Compare short circuit risk at different voltages
  - Quantitatively compare risk change with tin replacement with tin-lead
  - Evaluate risk associated with degrees of conformal coating coverage

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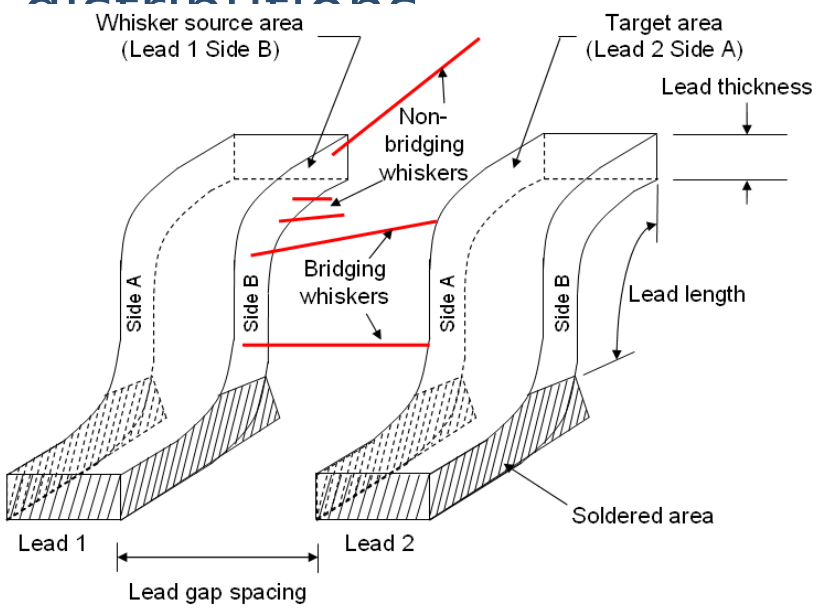
Purpose of the group

- Exercise the risk modeling spread-sheet
  - Perform case studies
  - Quantify mitigation
  - Provide inputs for improvement
  - Review and provide guidance on whisker length and area density distributions
  - Review assumptions



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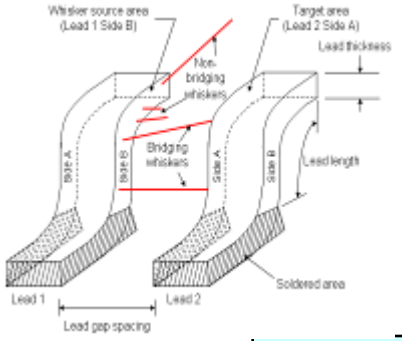
Monte Carlo short circuit modeling approach

Create bridging-risk model for various part types
- Monte Carlo developed lead-to-lead spacing distribution for various lead geometries and whisker angle distributions
- Time-independent model



Conformal coat mitigation
- Adjust whisker length, density, and diameter statistics
- Modify target area based on coverage data
- Modify source area based on "tenting" ability of coating

Information on whiskers: Length, density, diameter, etc.
- Data generated herein
- Published data
- Time and environment captured in whisker length, density, angle and diameter distributions

Evaluate published data on whisker electrical properties [2]

Apply data to a failure modes and effects analysis to determine functional impact

Use model to evaluate bridging risk
- Select representative digital, analog, and power circuits
- Compute total assembly whisker bridging for a give whisker length distribution

Evaluate overall risk of electrical functional impact
- Obtain a probability of each effect

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Assumptions

- Conservative
  - Whisker conduction probability is based on gold probe against tin rather than tin-tin contact
- Non-conservative
  - Whiskers from opposite surfaces are not interacting
    - No dueling sabers modeled
    - Whiskers changing azimuth angle during growth and hitting other whiskers is not modelled
  - No electric attraction between whiskers and substrates or between whiskers on adjacent surfaces is modeled
    - Whisker in video is ~ 10 microns in diameter with 50V applied
    - https://nepp.nasa.gov/whisker/experiment/exp4/index.html
      - Smaller diameter whisker would require less voltage to move
      - Longer whisker would be easier to move with a given voltage
    - Electrostatic charge on the insulator ~couple kV charge
    - https://nepp.nasa.gov/whisker/video/Zn-whiskers-HDG-electrostatic-bend.wmv
  - Whiskers are not moving due to air currents
    - https://nepp.nasa.gov/whisker/video/whisker-motion-air.mpg
  - Not considering fusing currents as a function of whisker diameter
- Other
  - Metal vapor arcing not considered
    - https://nepp.nasa.gov/whisker/anecdote/2009busbar/index.html

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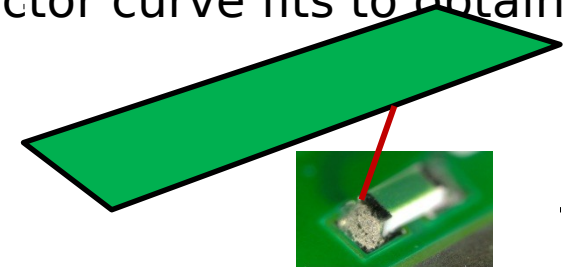
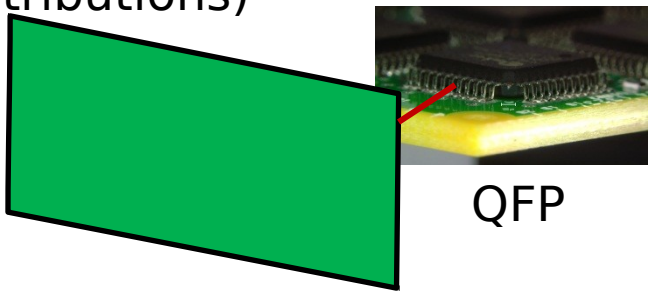
Model variations

- Complete: Adjacent shorting between QFP leads
- In process: Generic model elements for underside of connectors(all equal sizes)
  - Parallel plate
  - Parallel round lead and
  - Perpendicular plate
  - An integral form for parallel plate shape factor that agrees with the Monte Carlo but needs to be integrated numerically
  - Empirical correlations for the shape factors for the new cases.
  - The distributions which will need a little work to come up with a simplified model
- Next: Some selected cases of unequal parallel plates for use when a tin plated surface is opposite a part lead (can’t do generic view factor curve fits to obtain spacing distributions)





QFP

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Whisker parameters:
Length reference distributions

Tin source	Thickness (microns)	Substrate	Environmental exposure	Maximum observed whisker length (microns)	Lognormal μ (ln mm)	Lognormal σ	Density (whiskers /mm²)
SAC305 Solder [1][2]	3 to 25	Copper board pads (clean parts and board)	1,000 hours 85°C/85 %RH	76	-4.978	0.710	297 to 1,454 (4,000 hr level)
	3 to 25	Copper board pads (contaminated parts and board)		186 (Note 1)	-4.795	0.6962	
Plated Sn [3]	5 to 9	Copper C194	2.5 years room, 1,000 cycles -55 to 85°C, 2 months 60°C/85%RH	39	-4.571	0.9866	2,192 to 3,956
	7 to 9	Nickel plating over Copper C194		greater than 200 (Note 1)	-4.306	0.8106	126 to 3,573
Plated Sn Dunn [4] evaluated in [5]	5	Copper plated brass (specimen 11)	15.5 years: 3.5 years room temp. and humidity, 12 years in a dessicator with dry room air	1,000 maximum specimen 11 length	-2.651	0.9212	Not available
				733, average of specimen 11 maximum lengths at various locations	-2.783	0.8592	

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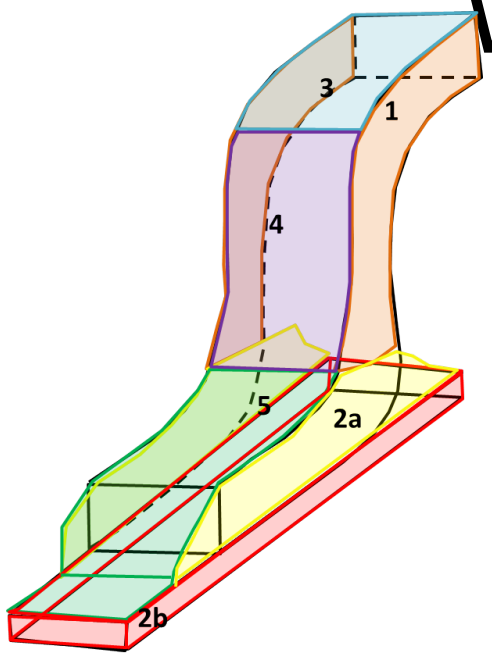
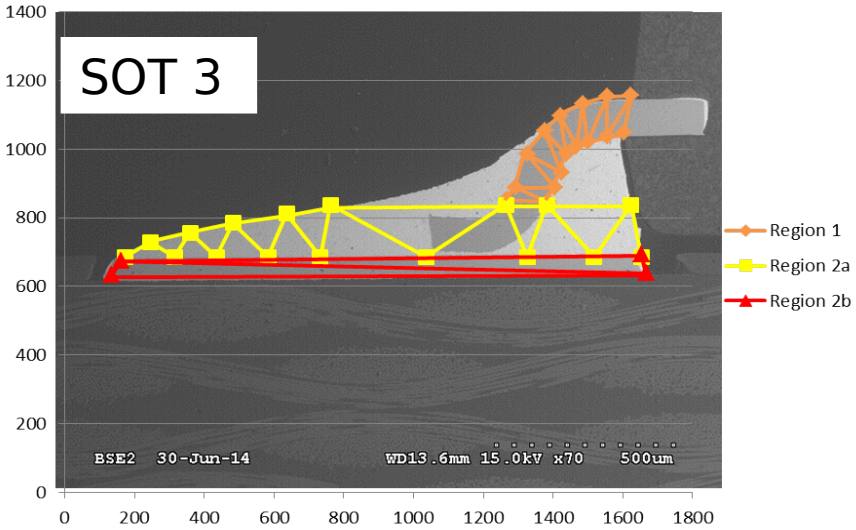
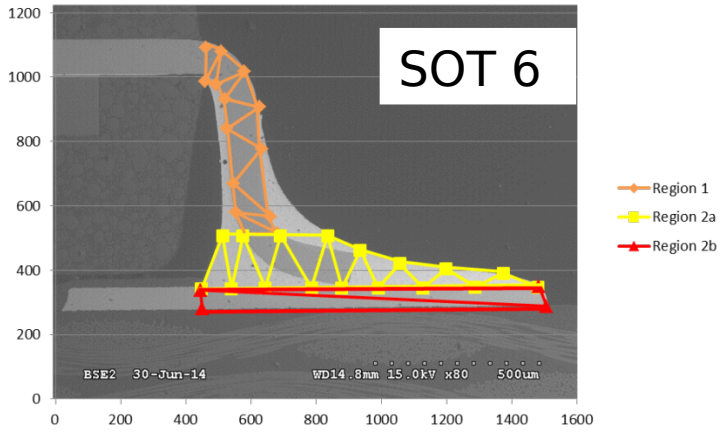
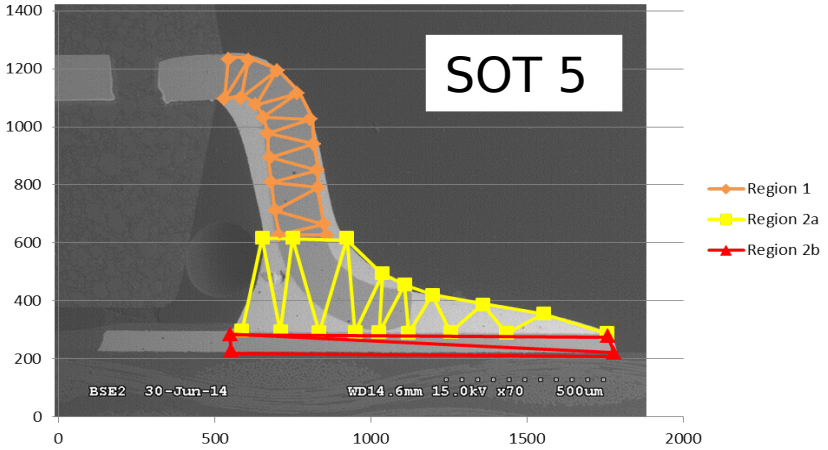
Whisker densities









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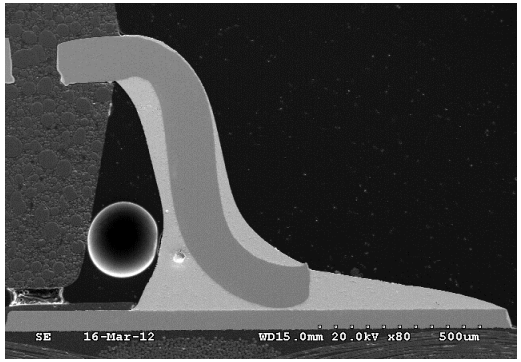
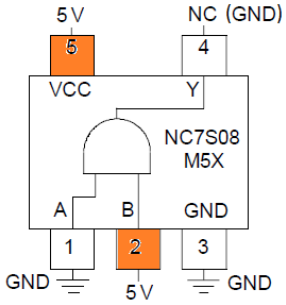
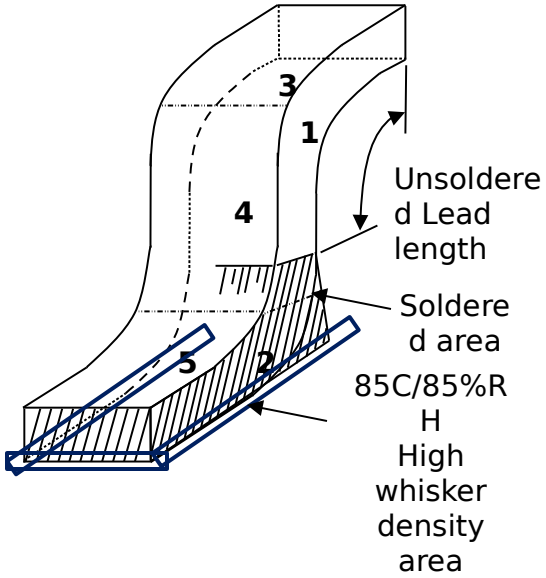
Whisker parameters: Density

Whisker count for SOT5 at 0-0 Cleanliness level 4,000 hr 85 ▼C/85RH [1]







	Whiskers per board pad	Whisker density (whiskers/mm²)
Minimum	58	297
Maximum	284	1454
Average	182.8	936

	Whiskers per lead on the side	Whisker density (whiskers/mm²)
Minimum	0	0
Maximum	44	236
Average	12.9	69

Maximum whisker density at the pad edge is 1454 whiskers/mm2

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Whisker densities (whiskers/mm²)

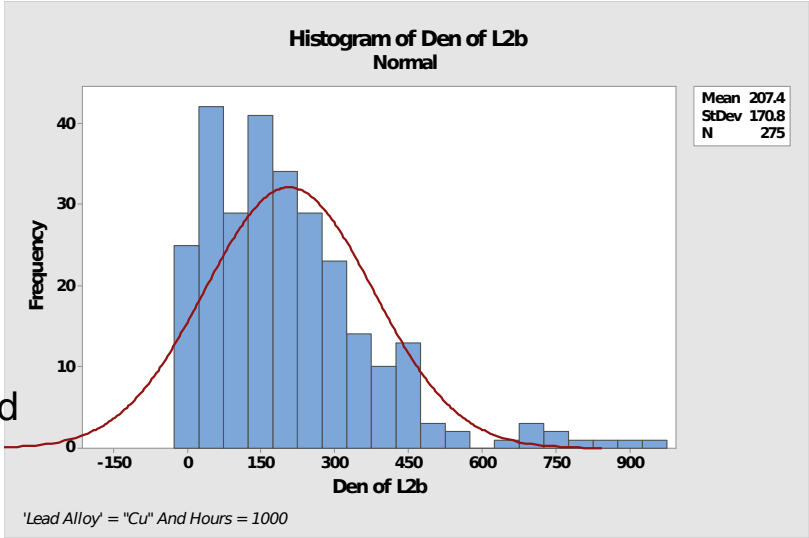
85°C/85%RH [1]Cu

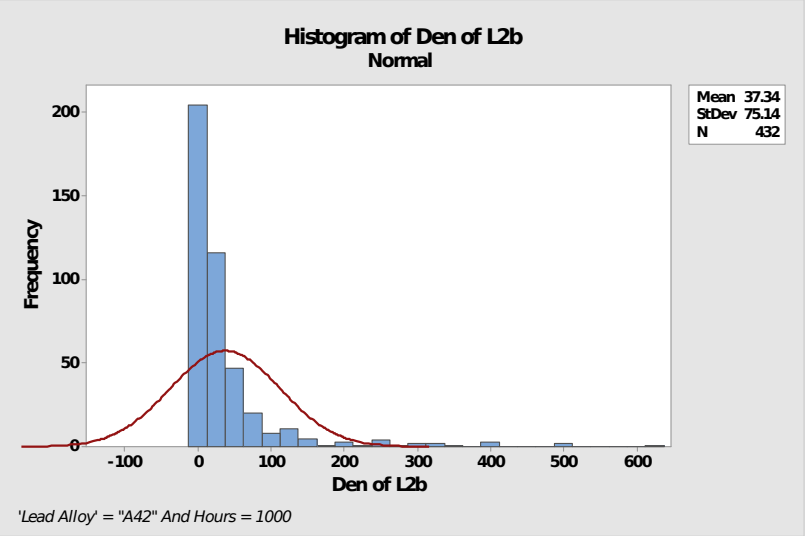
Location 2b

Alloy42

1000h

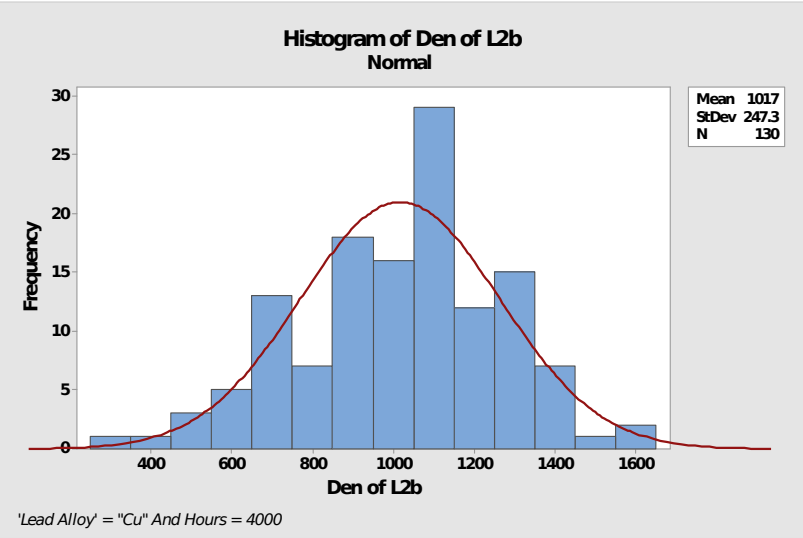
Normal Distribution not that good

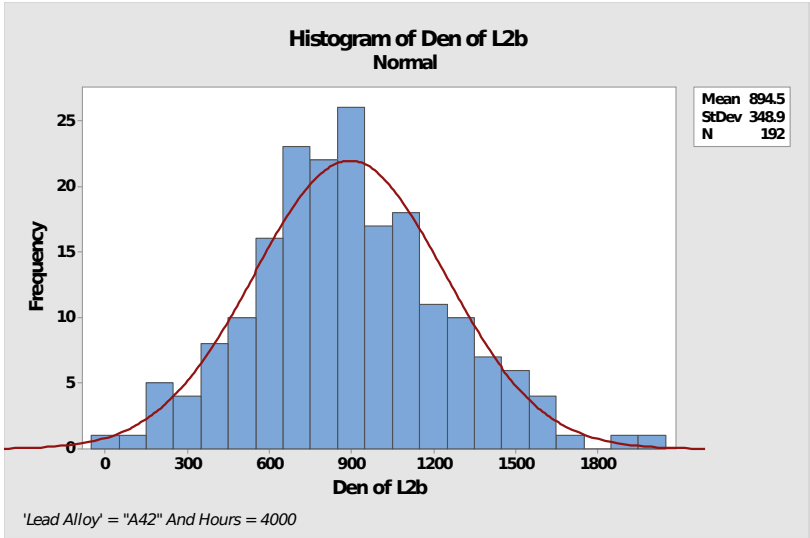




4000h

Normal Distribution better





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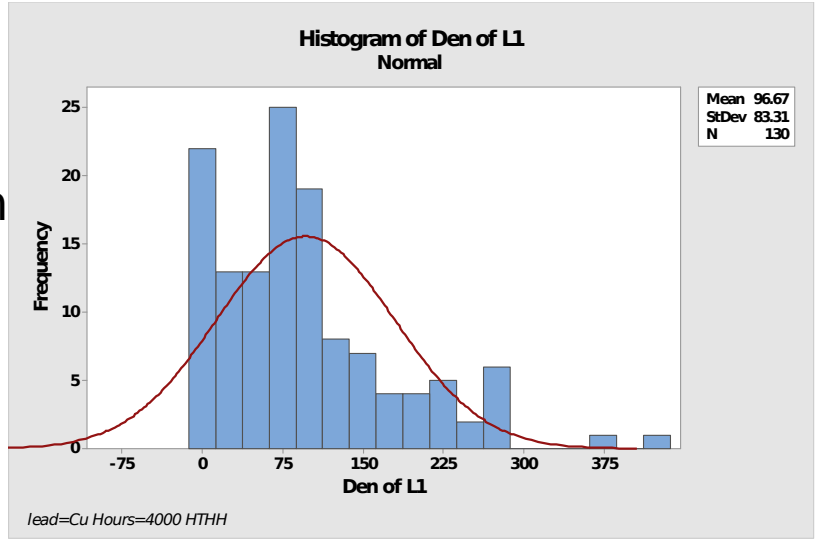
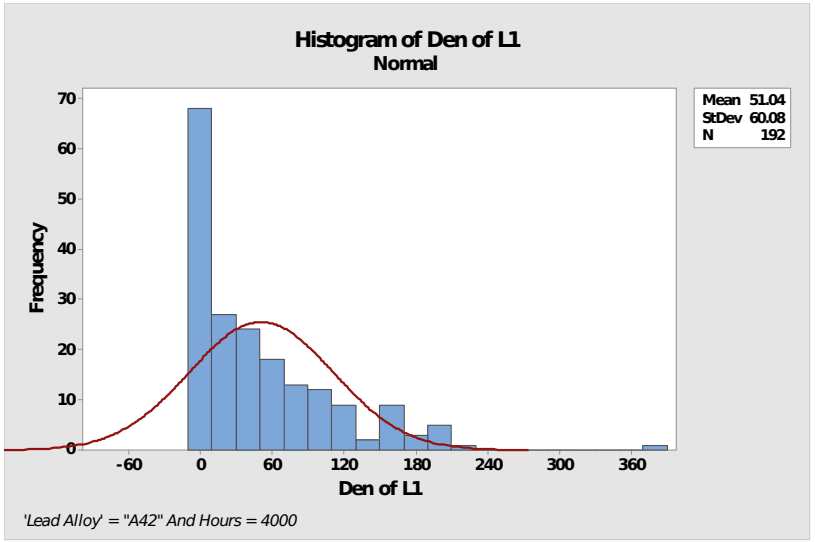
Whisker densities (whiskers/mm²)

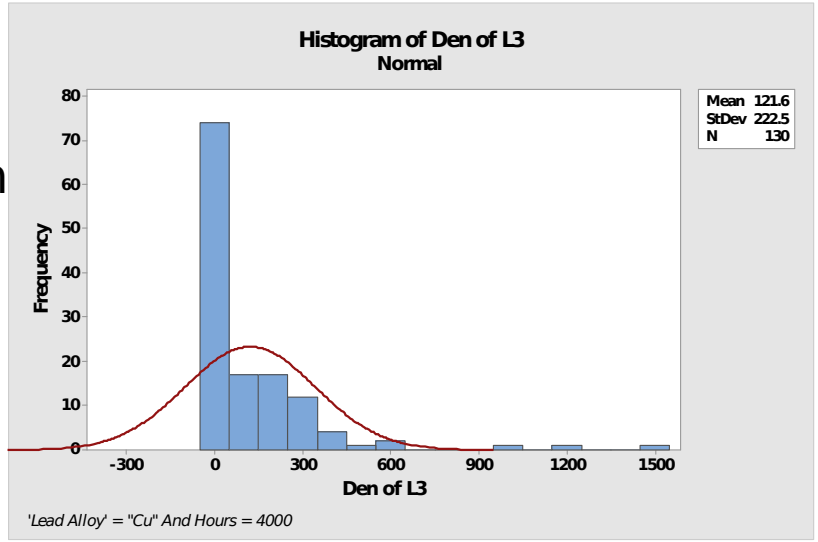
85°C/85%RH[1] Cu 4000h Alloy42

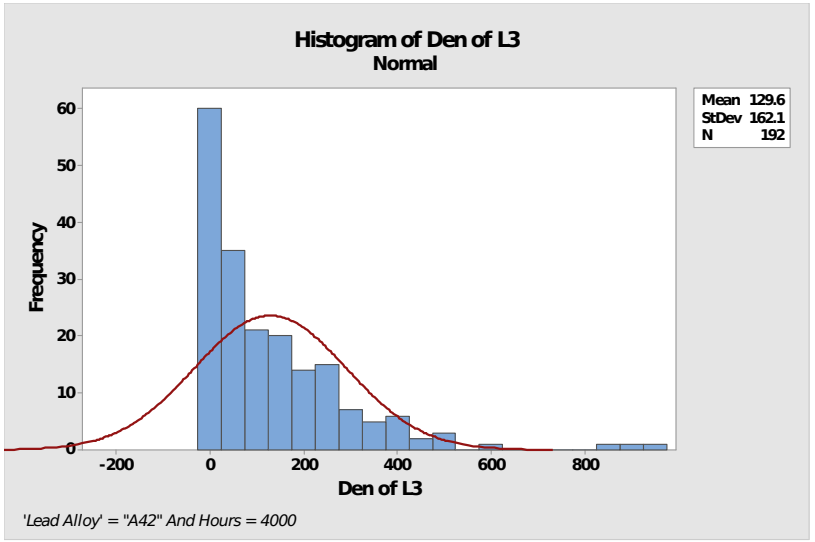
Location 1





Location 3





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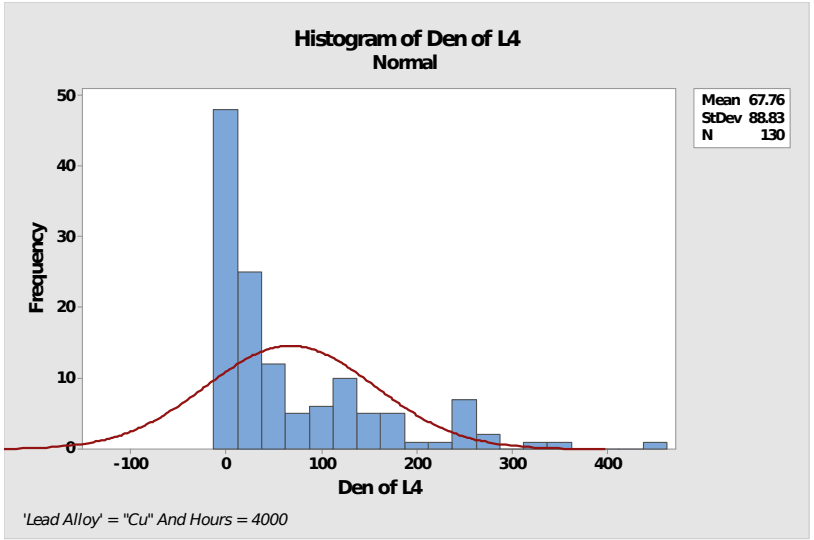
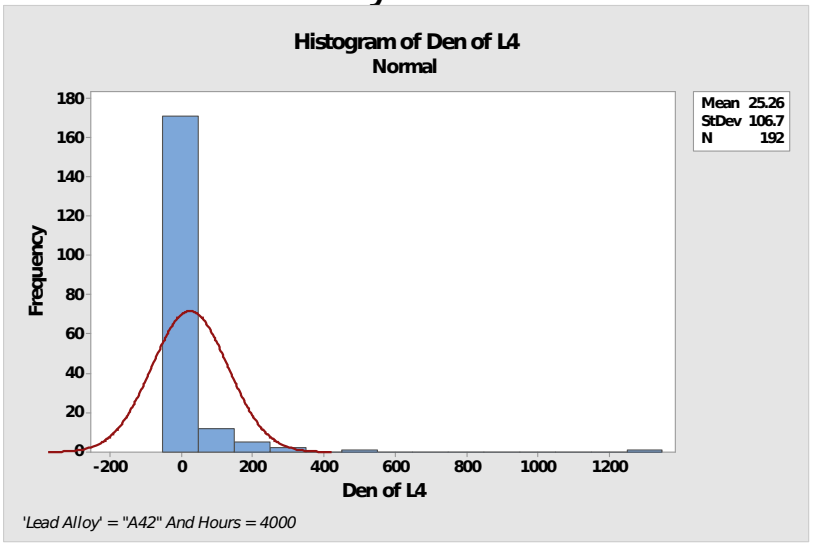
Whisker densities (whiskers/mm²)

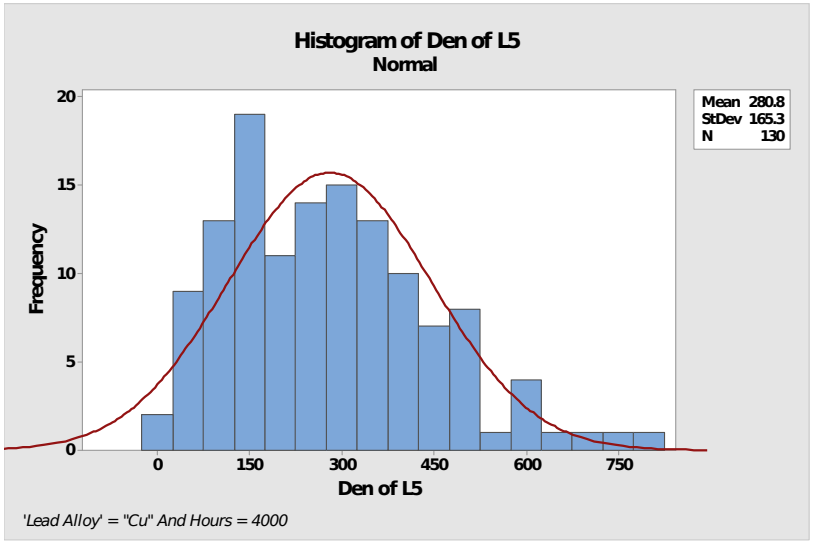
85°C/85%RH[1] Cu 4000h Alloy42

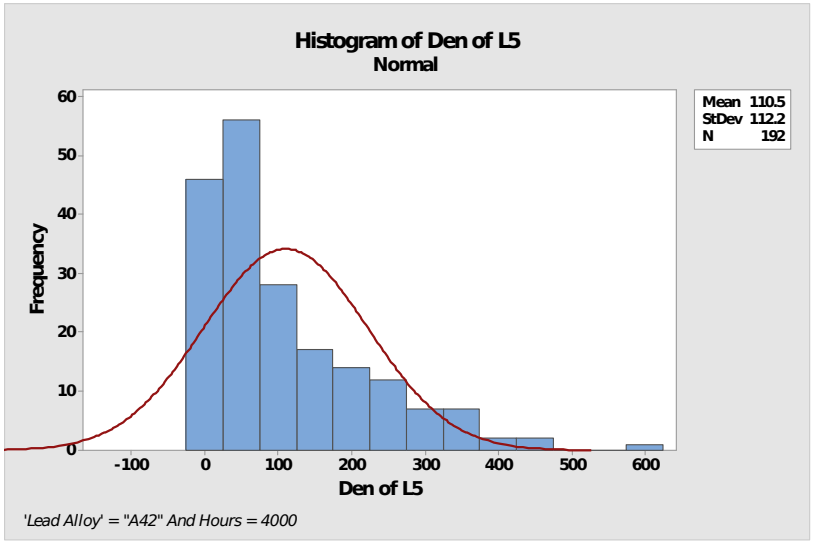
Location 4





Location 5





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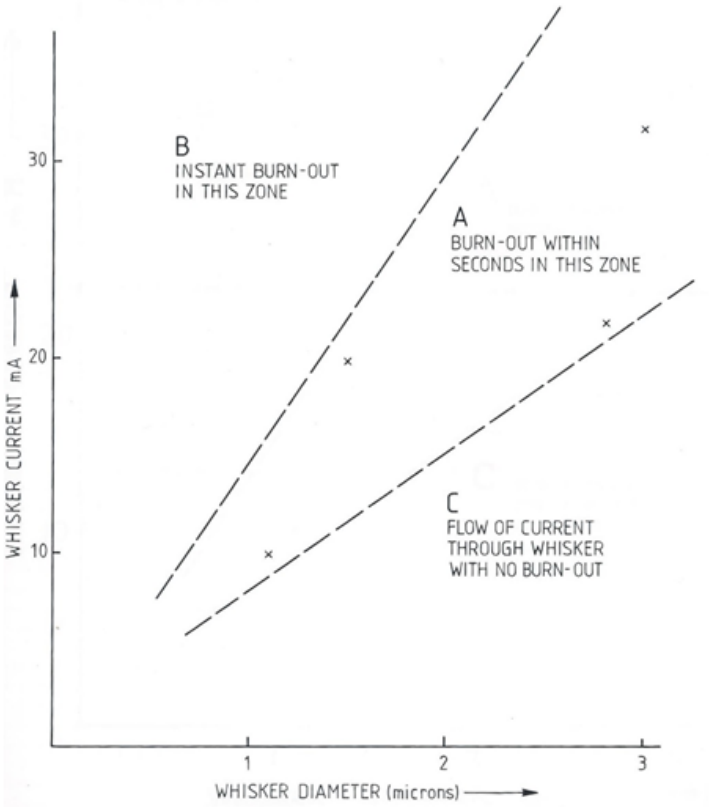
Fusing current

Graph to illustrate the effect of whisker diameter on possible short circuiting whisker (from plots of mA vs mV for four whiskers, relationship is linear until heating effects cause whisker burn out) [part of whisker characterization following intermittent short-circuit problem in 1985]



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Documents on Kavi site

- First risk model:
  - 2009-mccormack-whisker-bridging-assessment.pdf
    - Whisker length data
    - Dunn 2006 ES 15 years of whisker growth.pdf
    - Dunn 1987 Tin Whisker ESA-STR-223.pdf
- QFP risk model
  - meschter mckeown 2014 CALCE TW symp modeling-Final.pptx
  - TQFP128 example-whisker calculator.docx
  - Whisker_Risk_Model_3_2.xls
- Potential new distribution on 32 year data from Dunn
  - Investigation-Tin-Whisker-Growth-Dunn.pdf
  - 8th Int Symp on Tin Whiskers Dunn Ashworth FINAL.pptx
  - Whisker_Risk_Model_3_2-w dunn dist.xls

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Whisker risk modeling 8-81H roster

- Current Whisker risk modeling 8-81H roster
  - Joel Heebink
  - Dave Humphrey
  - Anduin Touw
  - Dave Hillman
  - Dave Pinsky
  - Barrie Dunn
  - Dave Burdick
  - Jeff Kennedy
  - Joe Juarez

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References

[1] S. Meschter, P. Snugovsky, J. Kennedy, Z. Bagheri, S. Kosiba; “SERDP Tin Whisker Testing and Modeling: High Temperature/High Humidity (HTHH) Conditions”; Defense Manufacturers Conference (DMC) December 2-5, 2013 Orlando, Florida

[2] S. Meschter, P. Snugovsky, J. Kennedy, Z. Bagheri, E. Kosiba, and A. Delhaise, SERDP Tin Whisker Testing and Modeling: High Temperature/High Humidity Conditions, International Conference on Solder Reliability (ICSR2013), Toronto, Ontario, Canada. May 13-15, 2014.

[3] Panashchenko, Lyudmyla; “Evaluation of Environmental Tests for Tin Whisker Assessment”; University of Maryland, Master’s thesis 2009

[4] Dunn, “15½ Years of Tin Whisker Growth – Results of SEM Inspections Made on Tin Electroplated C-Ring Specimens,” ESTEC Materials Report 4562, European Space Research and Technology Centre Noordwijk, The Netherlands; March 22, 2006

[5] McCormack, Meschter, “Probabilistic assessment of component lead-to-lead tin whisker bridging,” International Conference on Soldering and Reliability, Toronto, Ontario, Canada, May 20-22, 2009

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